Measuring Technology Adoption in Enterprise-Level Surveys: The Annual Business Survey

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Motivation and Findings

Current measures of firm technology adoption and use is limited

- Coverage
- Timeliness

Lack of comprehensive data on artificial intelligence, cloud computing and robotics prohibits studies on how advanced technologies are being used in production and their impact on the workforce

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Findings

- Adoption: Low and skewed (GPT versus Specialization)
- Technological Hierarchies
- Technology and Innovation

Annual Business Survey (ABS) Overview

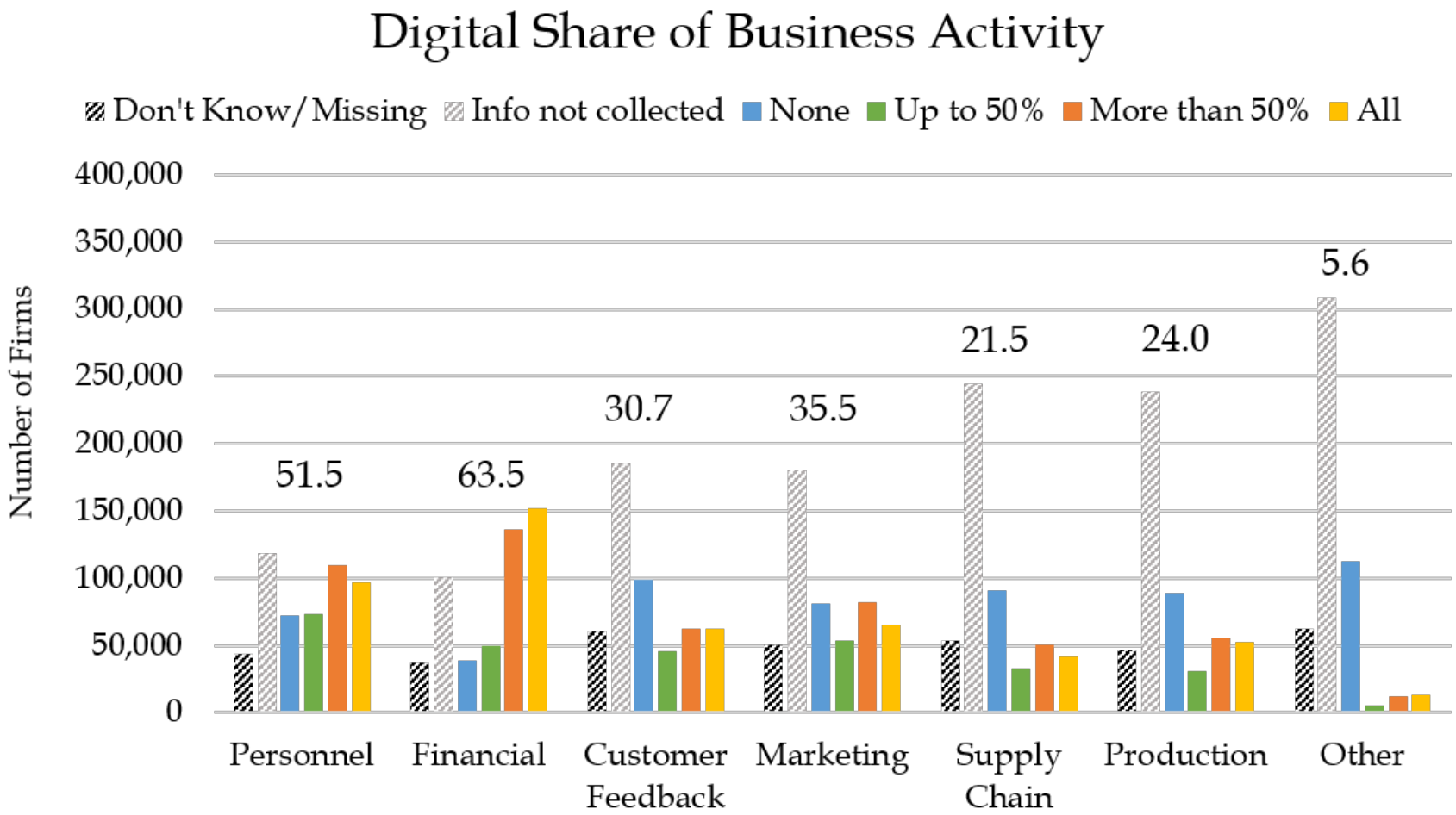
- First conducted in 2018, reference year 2017
- Joint with the National Science Foundation's National Center for Science and Engineering Statistics
- Enterprise-level; mailed to 850,000 nationally representative employer businesses ▸ Sampling ▸ Summary Statistics
  - Approximately 515,000 responded
- Combines 3 pre-existing surveys
  - Survey of Business Owners (SBO), Annual Survey of Entrepreneurs (ASE), Business R&D and Innovation Survey for Microbusiness (BRDIS-M)

Modules

- Introduce **new module each year** to measure new business topics (e.g., technology, globalization, innovation, finance)
  - 2018 ABS (Reference Year 2017) focuses on Digitization (Q1), Cloud Services (Q2) and new Business Technologies (Q3)
  - 2019 ABS (Reference Year 2018) will focus on technology adoption and the workforce

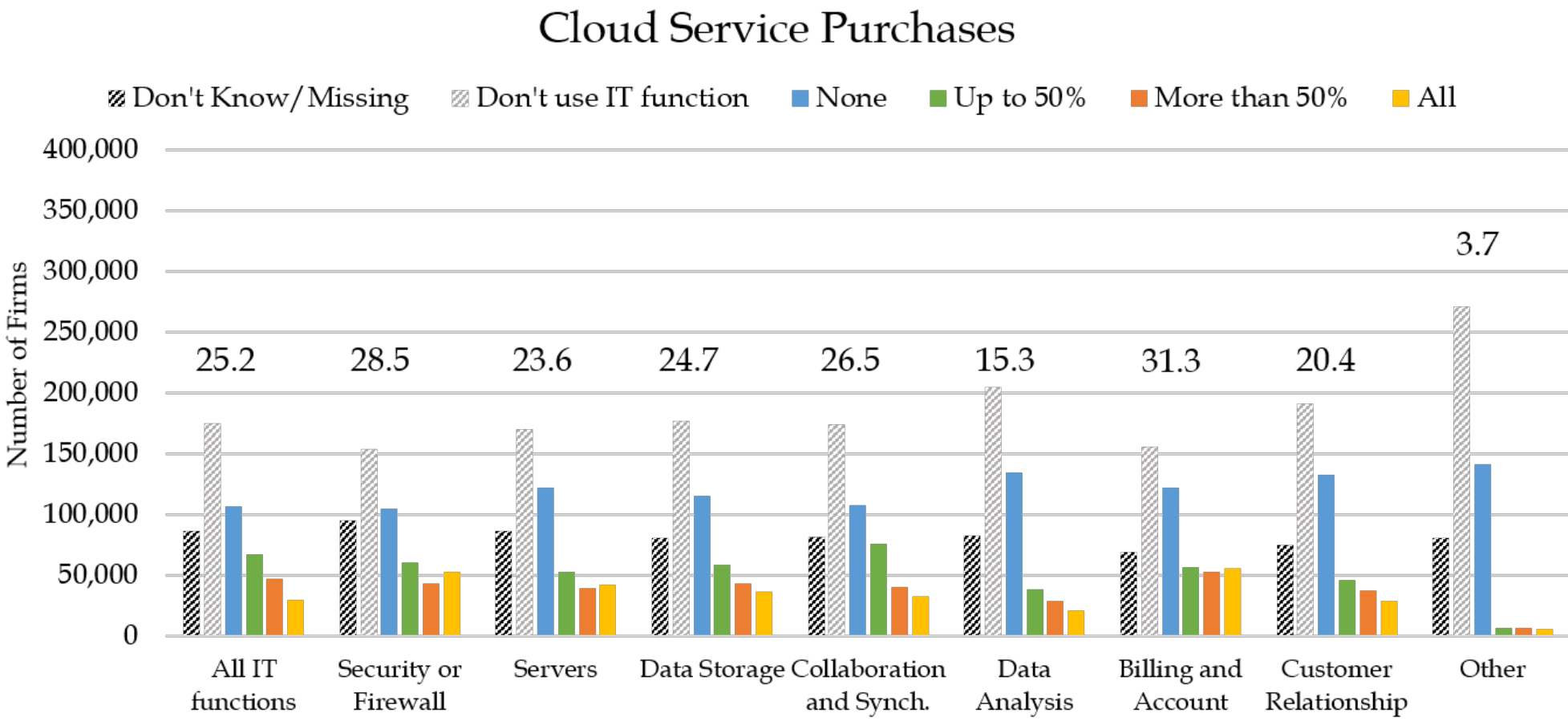
Digital Share of Business Activity (Q1)

In 2017, how much of each type of information was kept in digital format at this business?



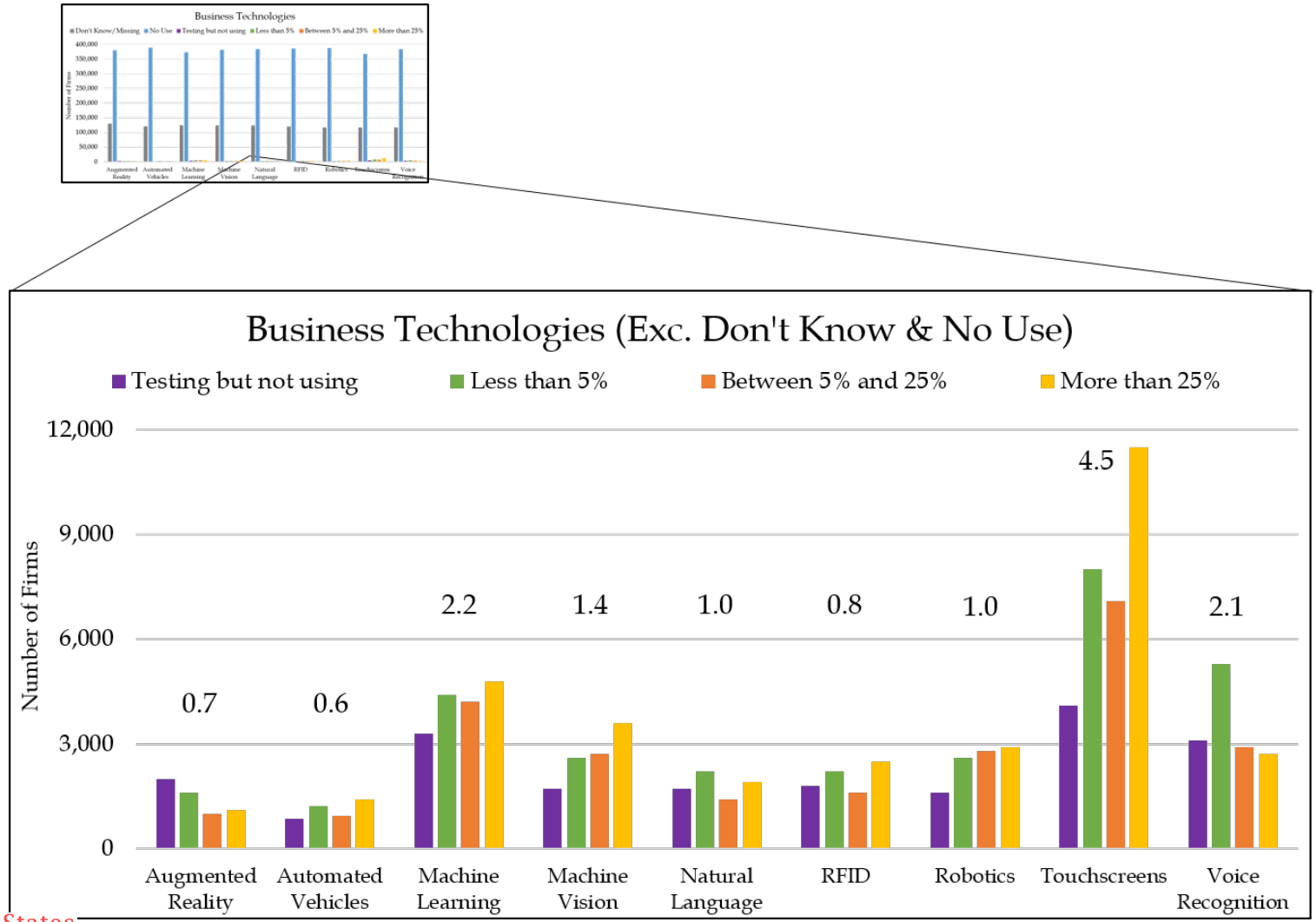
Cloud Service Purchases (Q2)

Considering the amount spent on each of these IT functions, how much was spent on cloud services?



Business Technologies (Q3)

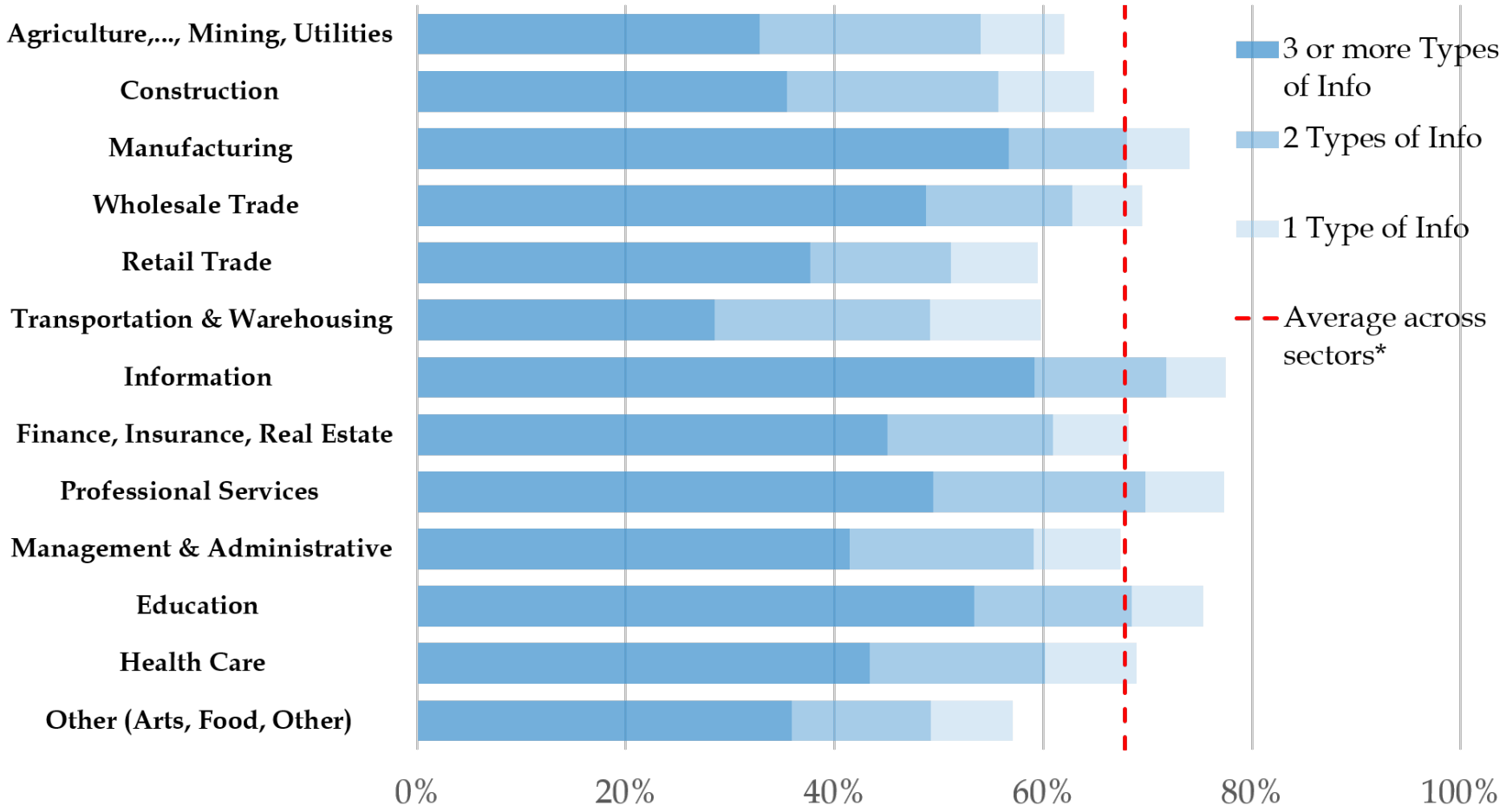
In 2017, to what extent did this business use the following technologies in producing goods or services?



Diffusion by Sector - Digitization

- Diffusion of information kept in digital format is relatively high across all sectors (GPT)

▸ Top 3 Information Types ▸ Utilization Rates



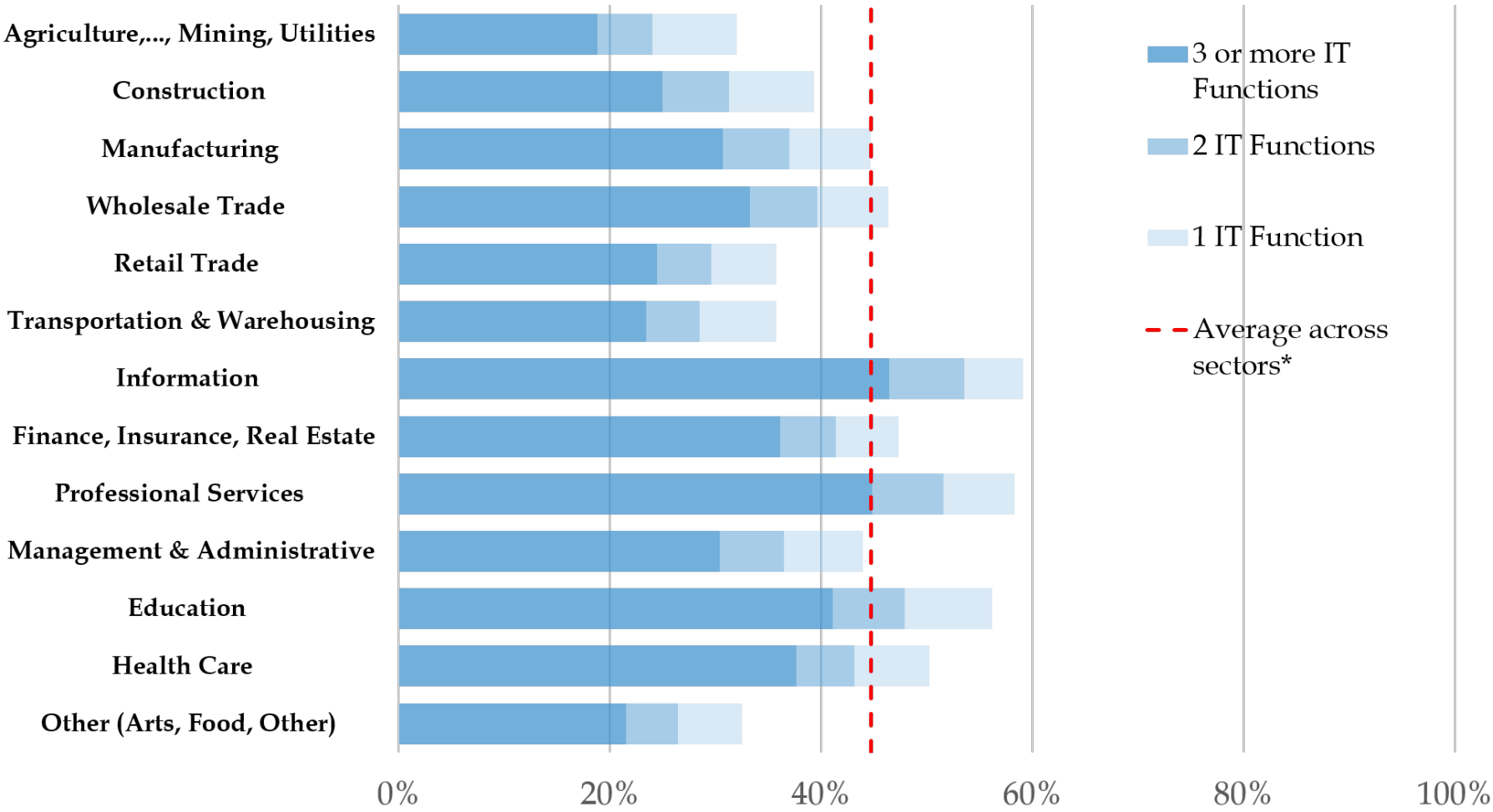
*Average is based on use of at least 1 type of digital info

United States Census Bureau

Diffusion by Sector - Cloud Services

- Diffusion of IT functions on the cloud is more variable

▸ Top 3 IT Functions ▸ Utilization Rates



*Average is based on use of at least 1 IT function in the cloud

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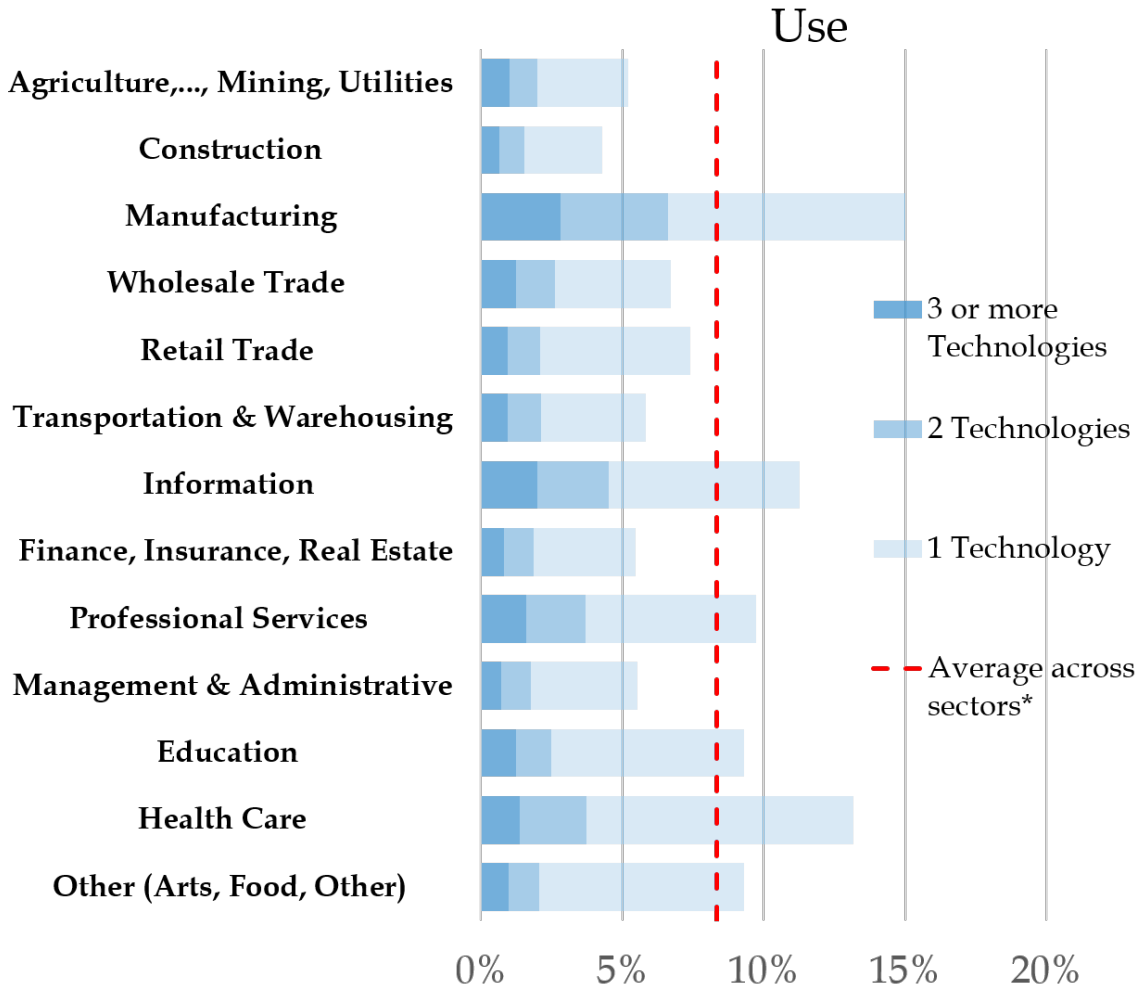
Diffusion by Sector - Business Technologies

- Diffusion of "advanced" business technologies is mostly low

▸ Top 3 Business Technologies ▸ Utilization Rates ▸ Top 3 Industries



*Average is based on use of at least 1 business technology

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Diffusion by Sector - Business Technologies

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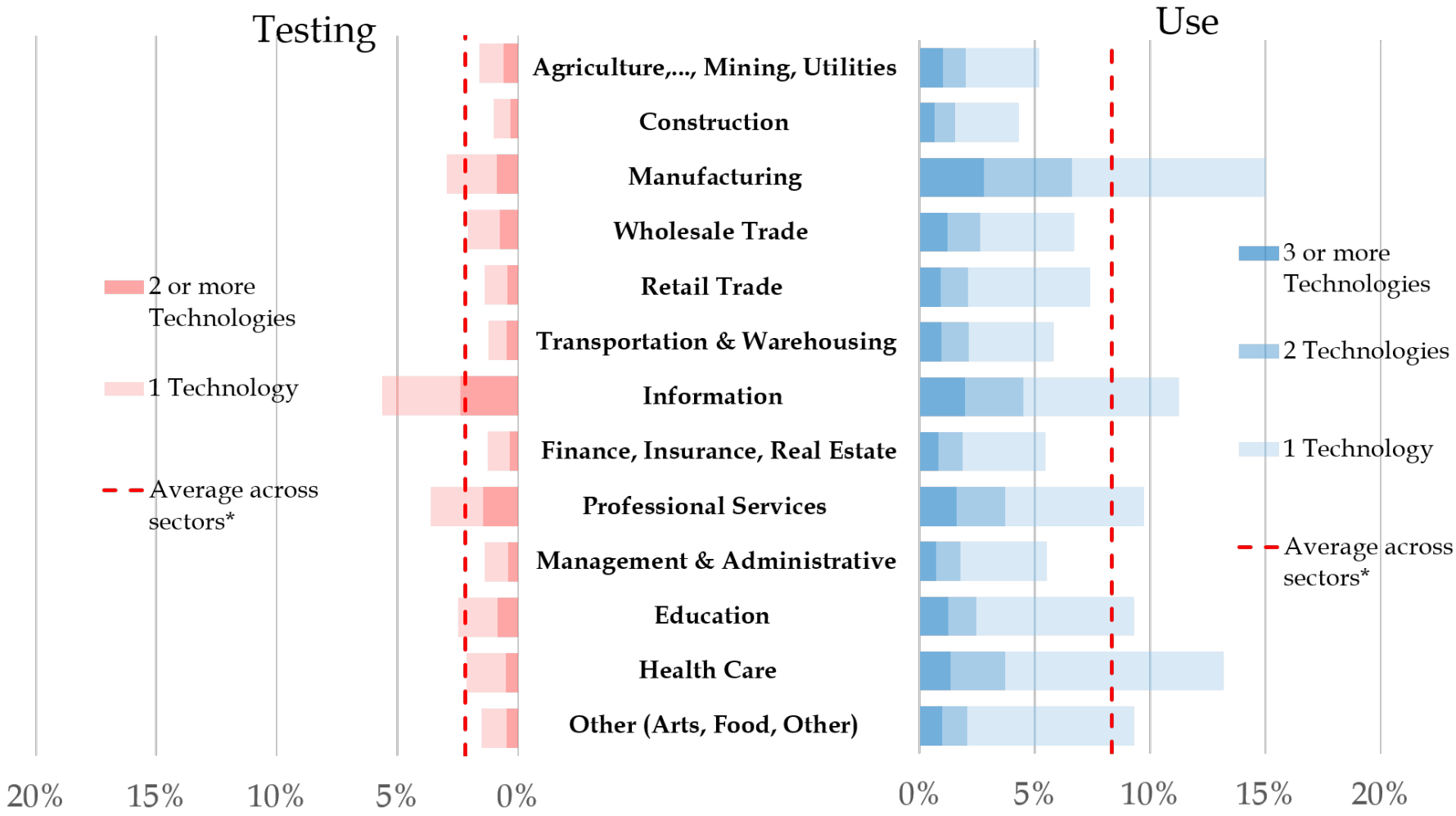
▸ Top 3 Business Technologies ▸ Utilization Rates ▸ Top 3 Industries



*Average is based on use of at least 1 business technology

Skewed Technology Use - Old and Large

- Oldest and largest firms are leading users of "advanced" business technologies
- Tech use increases with size for every age category

Table 1: Size-Age Predictors for Business Technology Use

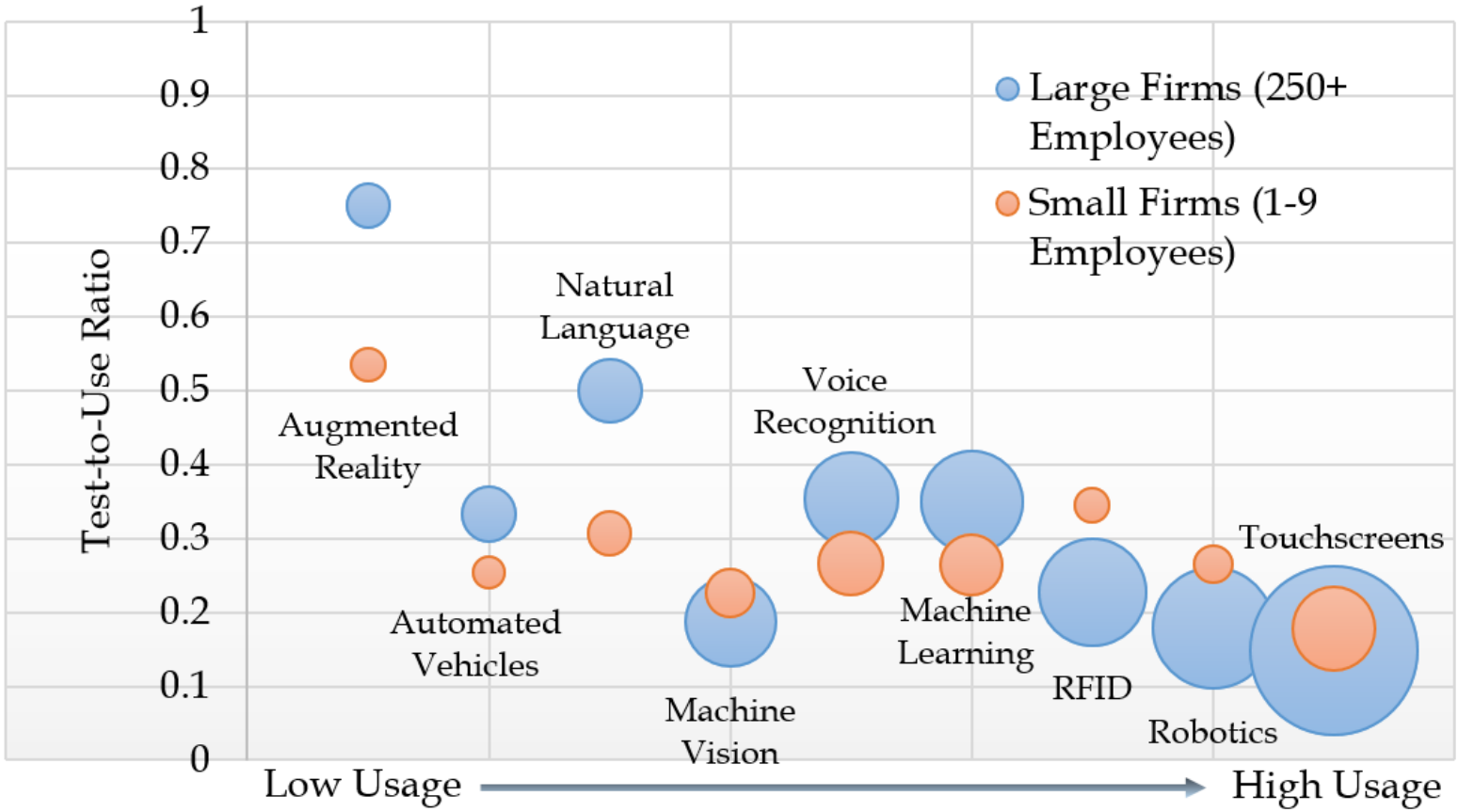
Age \ Size	1 to 9 Employees	10 to 49 Employees	50 to 249 Employees	250 or more Employees
0 to 5 Years	0.08	0.14	0.15	0.16
6 to 10 Years	0.07	0.13	0.16	0.16
11 to 20 Years	0.06	0.13	0.16	0.19
21 or more Years	0.06	0.11	0.19	0.25

*Table values are the estimated coefficients on size-age interactions in a linear probability model (LPM) regression
**All estimates are statistically significant at a significance level of 1%

▸ Other Technologies

Testing vs. Using - Large and Small Firms

- Largest firms generally lead smallest firms in both testing and use ▸ Full Sample



*Bubble size is proportional to usage rate
Technologies are sorted according to usage by **large firms

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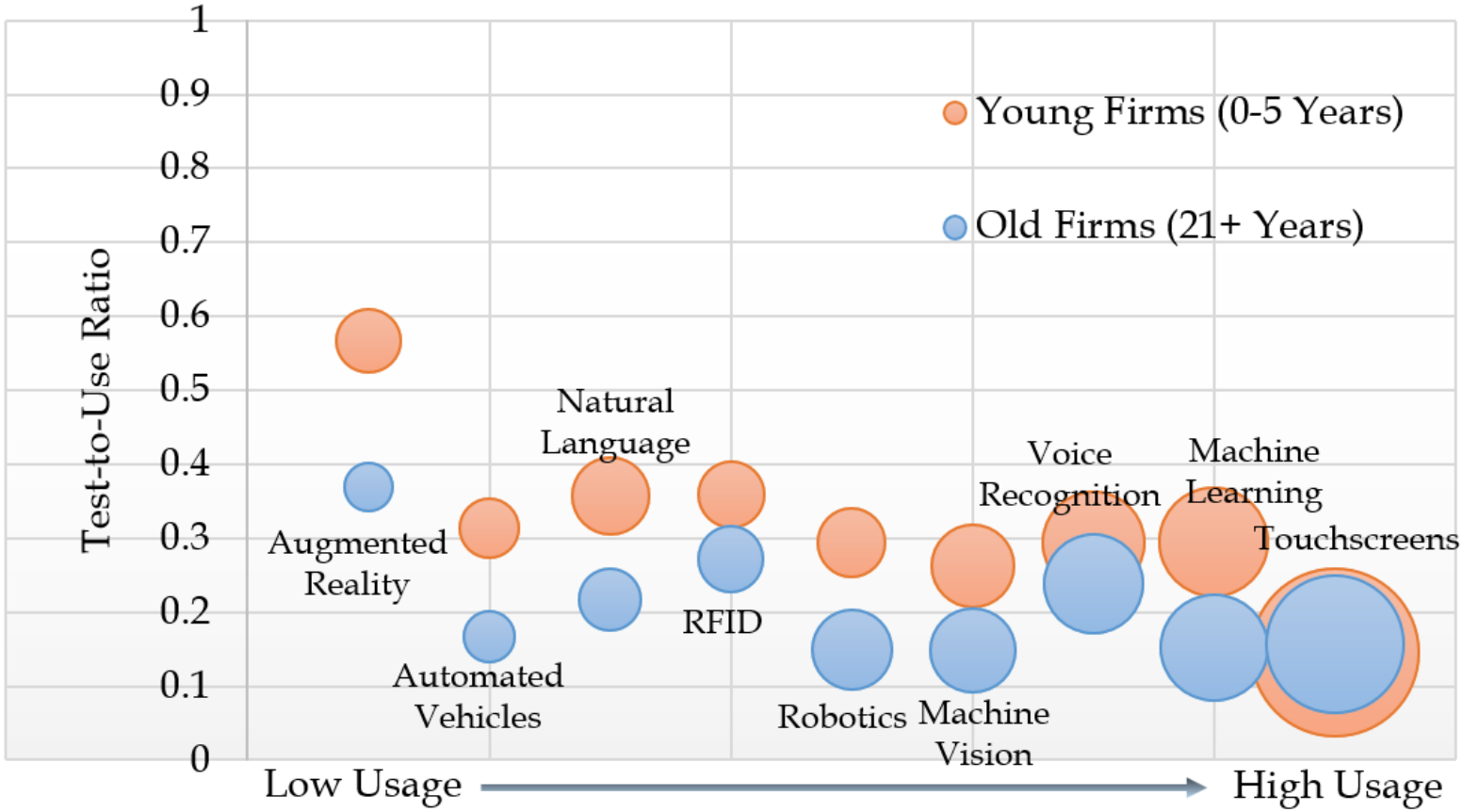
Testing vs. Using - Young and Old Firms

- Youngest firms test advanced technologies more than oldest firms (on average)



*Bubble size is proportional to usage rate
Technologies are sorted according to usage by **old firms

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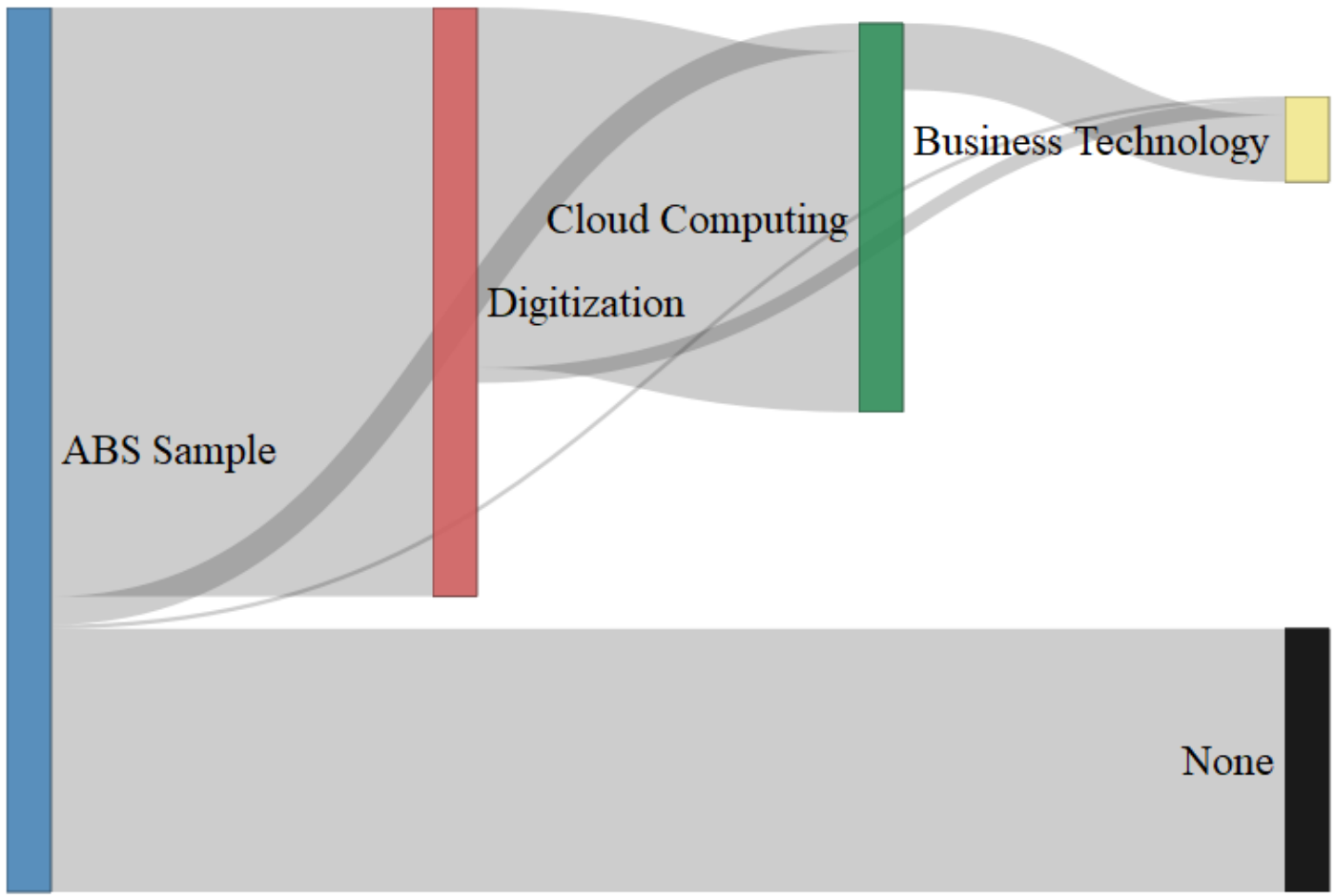
Technological Hierarchy

- Certain technological capabilities need to be fulfilled before firms can adopt new technologies

▸ Tech Complementarities

▸ ML Example



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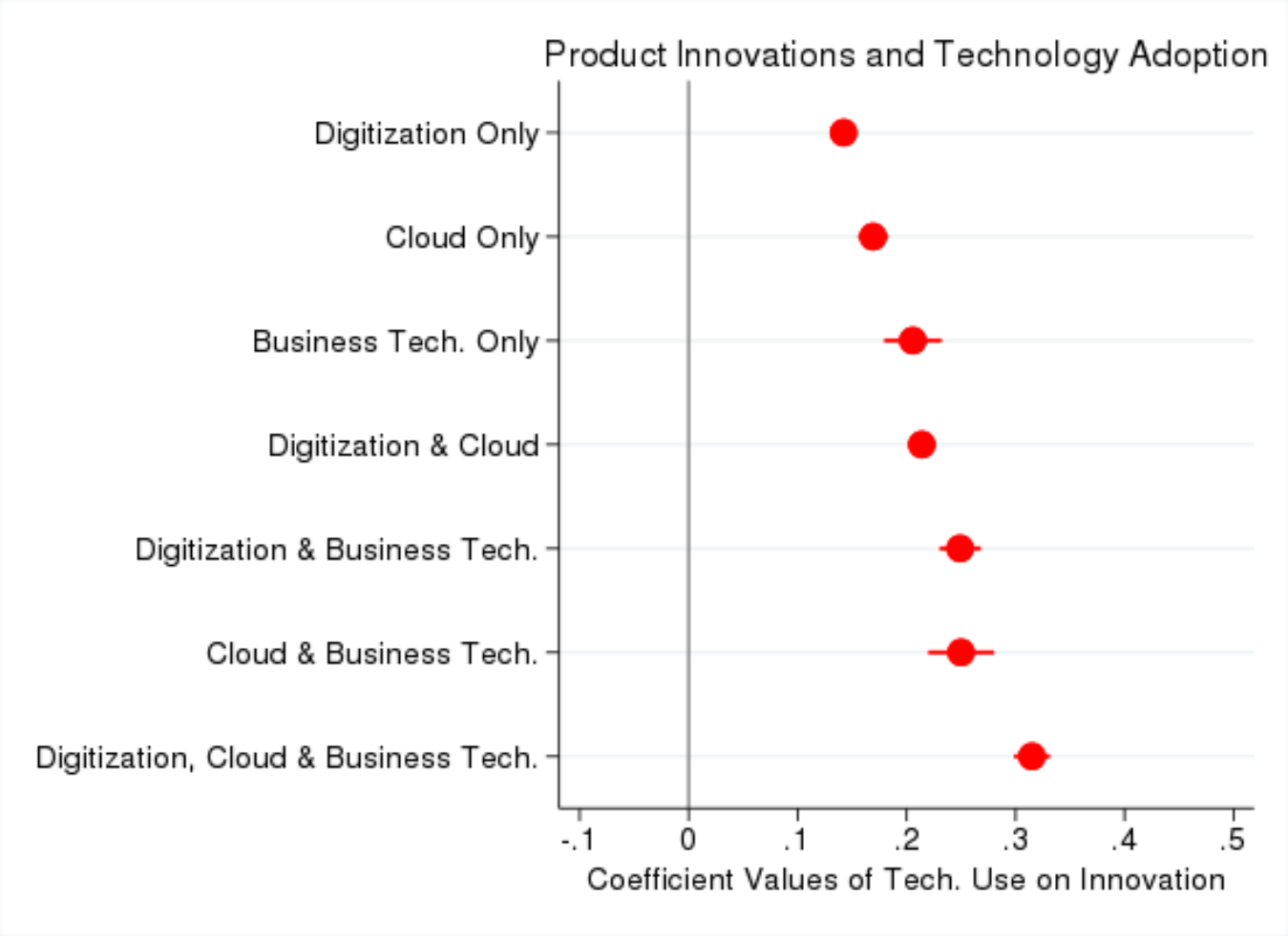
Innovation and Technology

- Intensive adopters of technology have higher levels of both product and process innovations

▸ Process Innovation ▸ Tech Breakdown



*LPM model with innovation as outcome variable. Regressors include size, age, tech category and industry FE.

Conclusion

- Introduced a new enterprise-level survey (ABS) with a new technology module that addresses primary concerns of data collection efforts
  - **First production tables available in Spring or Summer 2020 and may be requested by FSRDC users**
- Will bring back the module for the 2021 ABS (with improvements)
- Current module can start to address several open topics on technology in the digital age
  - Adoption: Low and Skewed (GPT versus Specialization)
  - Technological Hierarchies
  - Technology and Innovation

Appendix

Census ABS Page - https://www.census.gov/programs-survey/abs.html

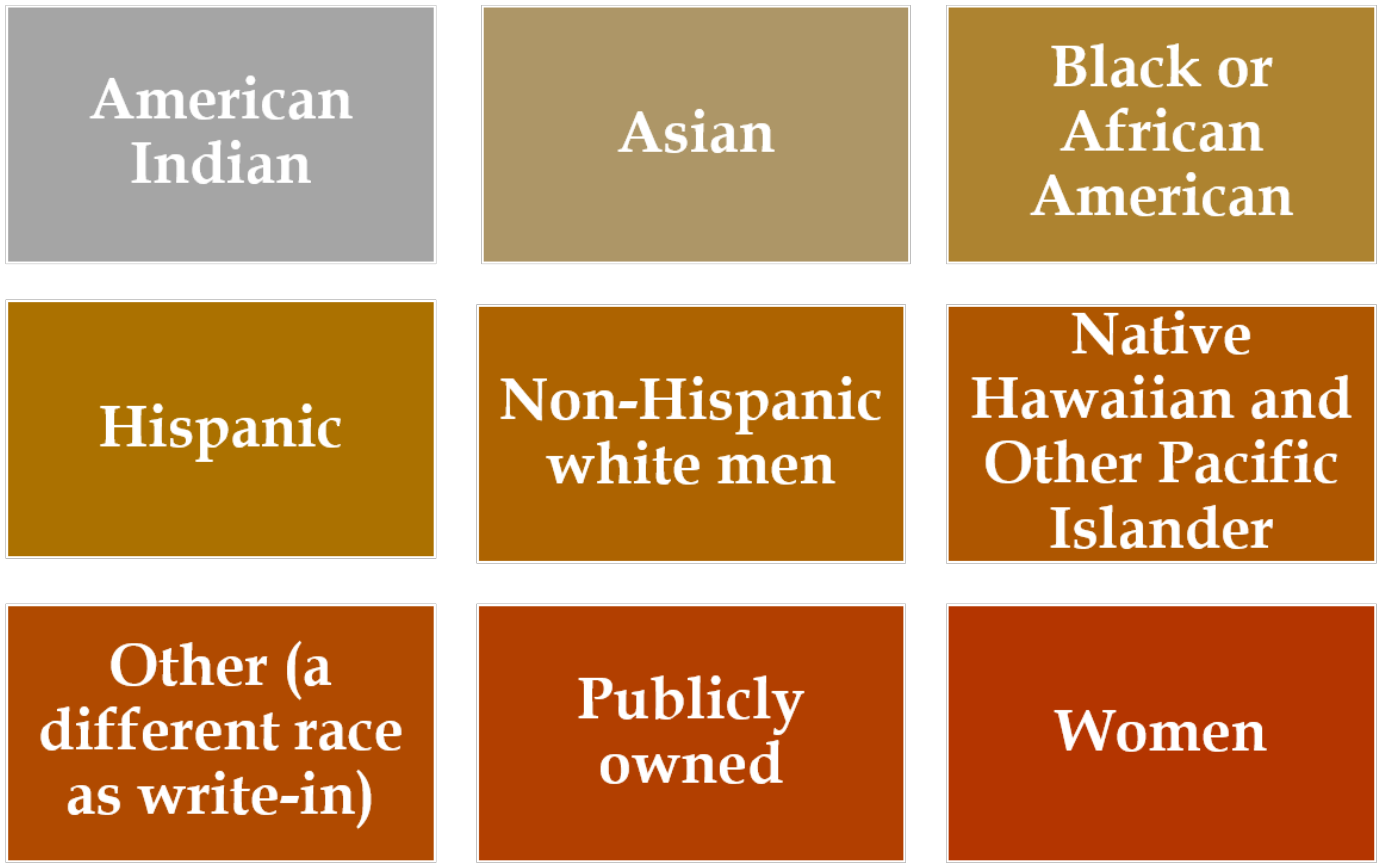
Appendix: Sampling

- The 2018 ABS sampling is stratified by ownership status, industry, and state from the 2017 Business Register
- Uses adminsitrative data to estimate probability that firm is minority- or women-owned
- Each firm is placed in one of 9 ownership frames for sampling
- Large companies are selected with certainty based on volume of sales, payroll, or number of paid employees
- Certain R&D industries are selected with certainty (e.g. NAICS 5417)
- R&D module (BRDIS-M) only applied for businesses with fewer than 10 employees

Appendix: Sampling (Cont.)

The 9 ownership frames are as follows:

Figure 1: Nine Sampling Ownership Frame



Appendix: Summary Statistics

Table 2: Summary Statistics

		Employment		Age	
	Observations	Mean	Std. Dev.	Mean	Std. Dev.
Unweighted	514,000**	94.11	1844	17.05	12.55
Weighted	3,070,000	22.99	755	15.84	11.84
BDS*	5,165,983	24.05	—	—	—

*Business Dynamics Statistics (2016)
**Our sample is less than 850,000 because it excludes firms who either ceased operations or were born in 2017

Table 3: Firm Size Distribution

Employment	(%)	Weight (%)	BDS*
1 to 9	64	76	76
10 to 49	24	20	20
50 to 249	9	3	4
250 or more	3	1	1

*Business Dynamics Statistics (2016)

Table 4: Firm Age Distribution

Age (years)	(%)	Weight (%)	BDS*
0 to 5	22	23	33
6 to 10	17	18	17
11 to 20	27	28	23
21 or more	34	30	27

*Business Dynamics Statistics (2016)

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Appendix: Summary Statistics (Cont.)

Table 5: Sectoral Distribution

NAICS	Sector	(%)	Weight (%)
11,21-22	Agriculture,..., Mining, Utilities	1	1
23	Construction	10	13
31-33	Manufacturing	9	5
42	Wholesale Trade	5	5
44-45	Retail Trade	14	12
48-49	Transportation and Warehousing	4	3
51	Information	2	1
52-53	Finance, Insurance, Real Estate	9	10
54	Professional Services	16	15
55-56	Management and Administrative	5	6
61	Education	1	1
62	Health Care	9	12
71-72,81	Other (Arts, Food, Other)	14	17

▸ Resume ▸ Appendix

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Top 3 Information Types in Digital Format (Q1)

- Finance, Personnel and Marketing are the three most common types of information digitized across all sectors

Sector	Highest Use		
	1st	2nd	3rd
Agriculture,..., Mining, Utilities	Finance	Personnel	Production
Construction	Finance	Personnel	Marketing
Manufacturing	Finance	Personnel	Production
Wholesale Trade	Finance	Personnel	Marketing
Retail Trade	Finance	Personnel	Marketing
Transportation and Warehousing	Finance	Personnel	Marketing
Information	Finance	Personnel	Marketing
Finance, Insurance, Real Estate	Finance	Personnel	Marketing
Professional Services	Finance	Personnel	Marketing
Management and Administrative	Finance	Personnel	Marketing
Education	Finance	Personnel	Marketing
Health Care	Finance	Personnel	Marketing
Other (Arts, Food, Other)	Finance	Personnel	Marketing

▸ Resume ▸ Appendix

Top 3 IT Functions Using Cloud Services (Q2)

- Billing, Security and Synchronization are the three most common IT functions based on the cloud across all sectors

Sector	Highest Use		
	1st	2nd	3rd
Agriculture,..., Mining, Utilities	Billing	Security	Data Storage
Construction	Billing	Security	Synchronization
Manufacturing	Billing	Security	Synchronization
Wholesale Trade	Billing	Security	Synchronization
Retail Trade	Billing	Security	Servers
Transportation and Warehousing	Billing	Security	All IT
Information	Synchronization	Billing	All IT
Finance, Insurance, Real Estate	Security	Billing	All IT
Professional Services	Synchronization	Security	All IT
Management and Administrative	Billing	Security	Synchronization
Education	Billing	Synchronization	Security
Health Care	Billing	Security	All IT
Other (Arts, Food, Other)	Billing	Security	Synchronization

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Top 3 Business Technologies Used (Q3)

- Different sectors utilize different advanced technologies

Sector	Highest Use		
	1st	2nd	3rd
Agriculture,..., Mining, Utilities	Machine Learning	Touchscreens	Machine Vision
Construction	Touchscreens	Machine Learning	Voice Recognition
Manufacturing	Machine Learning	Robotics	Touchscreens
Wholesale Trade	Touchscreens	Machine Learning	RFID
Retail Trade	Touchscreens	Machine Learning	RFID
Transportation and Warehousing	Touchscreens	Machine Learning	RFID
Information	Touchscreens	Machine Learning	Voice Recognition
Finance, Insurance, Real Estate	Touchscreens	Voice Recognition	Machine Learning
Professional Services	Voice Recognition	Touchscreens	Machine Learning
Management and Administrative	Touchscreens	Machine Learning	Voice Recognition
Education	Touchscreens	Machine Learning	Voice Recognition
Health Care	Touchscreens	Voice Recognition	Machine Learning
Other (Arts, Food, Other)	Touchscreens	Machine Learning	Machine Vision

▸ Resume ▸ Appendix

Utilization Rates for Digitzation

- Financial and Personnel information is most likely to be digitized

Table 6: Utilization Rates for Digitization (%)

Information Type	Using	Using Intensively	Using*
Financial	63.5	53.4	63.2
Personnel	51.5	38.1	57.5
Marketing	35.5	25.7	46.2
Feedback	30.7	22.1	41.7
Production	24.0	18.7	32.4
Supply Chain	21.5	15.6	35.0
Other Information	5.6	4.6	7.4

*Column 3 is weighted by employment in addition to sample weights

Utilization Rates for Cloud Services

- Cloud Service purchases are more evenly distributed across different IT functions

Table 7: Cloud Services Usage Rates (%)

IT Function	Using	Using Intensively	Using*
Billing	31.3	20.8	28.4
Security	28.5	17.9	31.5
Synchronization	26.5	13.3	30.1
All IT	25.2	14.0	32.6
Data Storage	24.7	14.6	30.3
Servers	23.6	14.7	30.2
Customer Relations	20.4	12.1	24.3
Data Analysis	15.3	9.0	23.5
Other IT Functions	3.7	2.5	4.8

*Column 3 is weighted by employment in addition to sample weights

Utilization Rates for Business Technologies

- Diffusion of "advanced" business technologies is low across all sectors
- AI-related technologies (machine learning, machine vision, natural language processing, automated guided vehicles) are not heavily utilized

Table 8: Business Technology Usage Rates (%)

Technology	Using	Testing	Using*
Touchscreens	4.5	0.7	13.2
Machine Learning	2.2	0.5	5.4
Voice Recognition	2.1	0.5	5.3
Machine Vision	1.4	0.3	3.4
Robotics	1.0	0.2	6.8
Natural Language Processing	1.0	0.3	3.5
RFID	0.8	0.3	5.2
Augmented Reality	0.7	0.3	1.3
Automated Guided Vehicles	0.6	0.1	1.6

*Column 3 is weighted by employment in addition to sample weights

Top 3 Industries that Use Each Business Technology

Table 9: Top 3 Industries Using Augmented Reality

NAICS	Industry	Usage Rate (%)
5121	Motion Picture and Video Industries	6.8
5112	Software Publishers	5.1
5415	Computer Systems Design and Related Services	4.1
-	Mean (All Industries)	1.1

Table 10: Top 3 Industries Using Automated Vehicles

NAICS	Industry	Usage Rate (%)
2373	Highway, Street, and Bridge Construction	2.4
1100	Agriculture, Forestry, Fishing and Hunting	2.3
4884	Support Activities for Road Transportation	1.8
-	Mean (All Industries)	0.8

Table 11: Top 3 Industries Using Machine Learning

NAICS	Industry	Usage Rate (%)
5112	Software Publishers	12.4
3327	Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	11.7
5415	Computer Systems Design and Related Services	11.4
-	Mean (All Industries)	3.1

Top 3 Industries that Use Each Business Tech. (Cont.)

Table 12: Top 3 Industries Using Machine Vision

NAICS	Industry	Usage Rate (%)
3327	Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	9.8
3261	Plastics Product Manufacturing	8.3
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufact.	7.8
-	Mean (All Industries)	1.8

Table 13: Top 3 Industries Using Natural Language Processing

NAICS	Industry	Usage Rate (%)
5415	Computer Systems Design and Related Services	6.8
5112	Software Publishers	6.7
5191	Other Information Services	6.3
-	Mean (All Industries)	1.4

Table 14: Top 3 Industries Using RFID

NAICS	Industry	Usage Rate (%)
4931	Warehousing and Storage	7.6
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufact.	5.1
5151	Radio and Television Broadcasting	4.2
-	Mean (All Industries)	1.4

Top 3 Industries that Use Each Business Tech. (Cont.)

Table 15: Top 3 Industries Using Robotics

NAICS	Industry	Usage Rate (%)
3261	Plastics Product Manufacturing	17.1
3345	Navigational, Measuring, Electromedical, and Control Instruments Manufact.	8.7
3327	Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	8.4
-	Mean (All Industries)	1.5

Table 16: Top 3 Industries Using Touchscreens/Kiosks

NAICS	Industry	Usage Rate (%)
3121	Beverage Manufacturing	15.9
6231	Nursing Care Facilities (Skilled Nursing Facilities)	14.9
7139	Other Amusement and Recreation Industries	13.3
-	Mean (All Industries)	5.9

Table 17: Top 3 Industries Using Voice Recognition Software

NAICS	Industry	Usage Rate (%)
6211	Offices of Physicians	12.1
5411	Legal Services	8.2
5415	Computer Systems Design and Related Services	7.9
-	Mean (All Industries)	2.8

▸ Resume ▸ Appendix

Size-Age Predictors for Digitization (Q1)

The values in the denominator (including Missing responses and/or Don't Know) may alter pattern of usage rates for digitization

Age \ Size	1 to 9	10 to 49	50 to 249	250 or more
0 to 5	0.67	0.71	0.69	
6 to 10	0.65	0.73	0.73	
11 to 20	0.64	0.75	0.77	
21 or more	0.61	0.75	0.78	

Size-Age Predictors for Cloud Services (Q2)

The values in the denominator (including Missing responses and/or Don't Know) may alter pattern of usage rates for digitization

Age \ Size	1 to 9	10 to 49	50 to 249	250 or more
0 to 5	0.46	0.52	0.50	
6 to 10	0.44	0.52	0.55	
11 to 20	0.41	0.52	0.56	
21 or more	0.36	0.50	0.55	

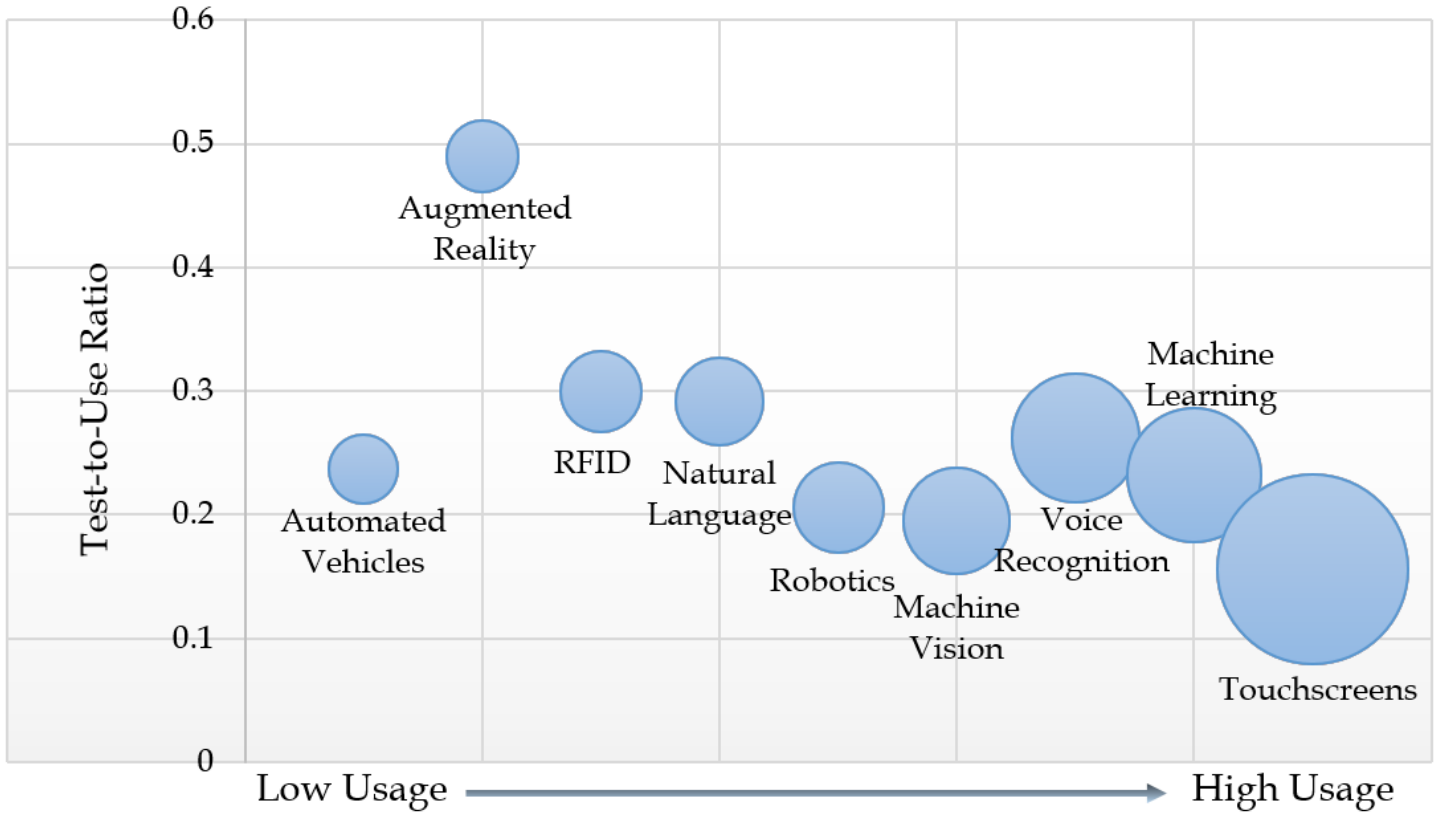
Size-Age Predictors for Business Technology Use (Q3) - Manufacturing Only

Manufacturing firms follow similar adoption patterns for advanced business technologies, with oldest and largest firms being the primary users

Age \ Size	1 to 9	10 to 49	50 to 249	250 or more
0 to 5	0.13	0.20	0.31	0.28
6 to 10	0.10	0.18	0.30	0.35
11 to 20	0.10	0.20	0.31	0.43
21 or more	0.08	0.19	0.31	0.37

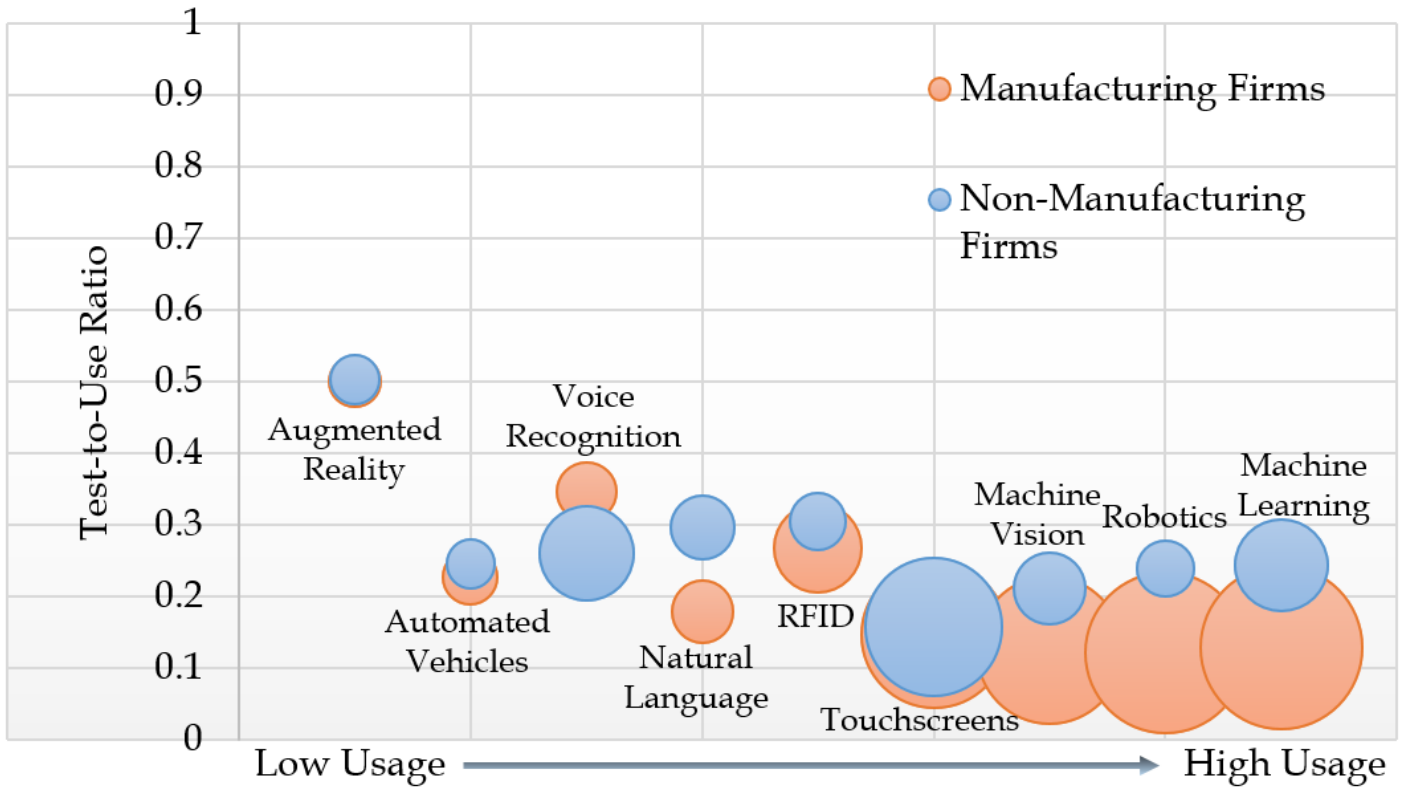
▸ Resume ▸ Appendix

Testing vs. Using - All sectors



*Bubble size is proportional to usage rate

Testing vs. Using - Manufacturing and Non-Manufacturing



*Bubble size is proportional to usage rate

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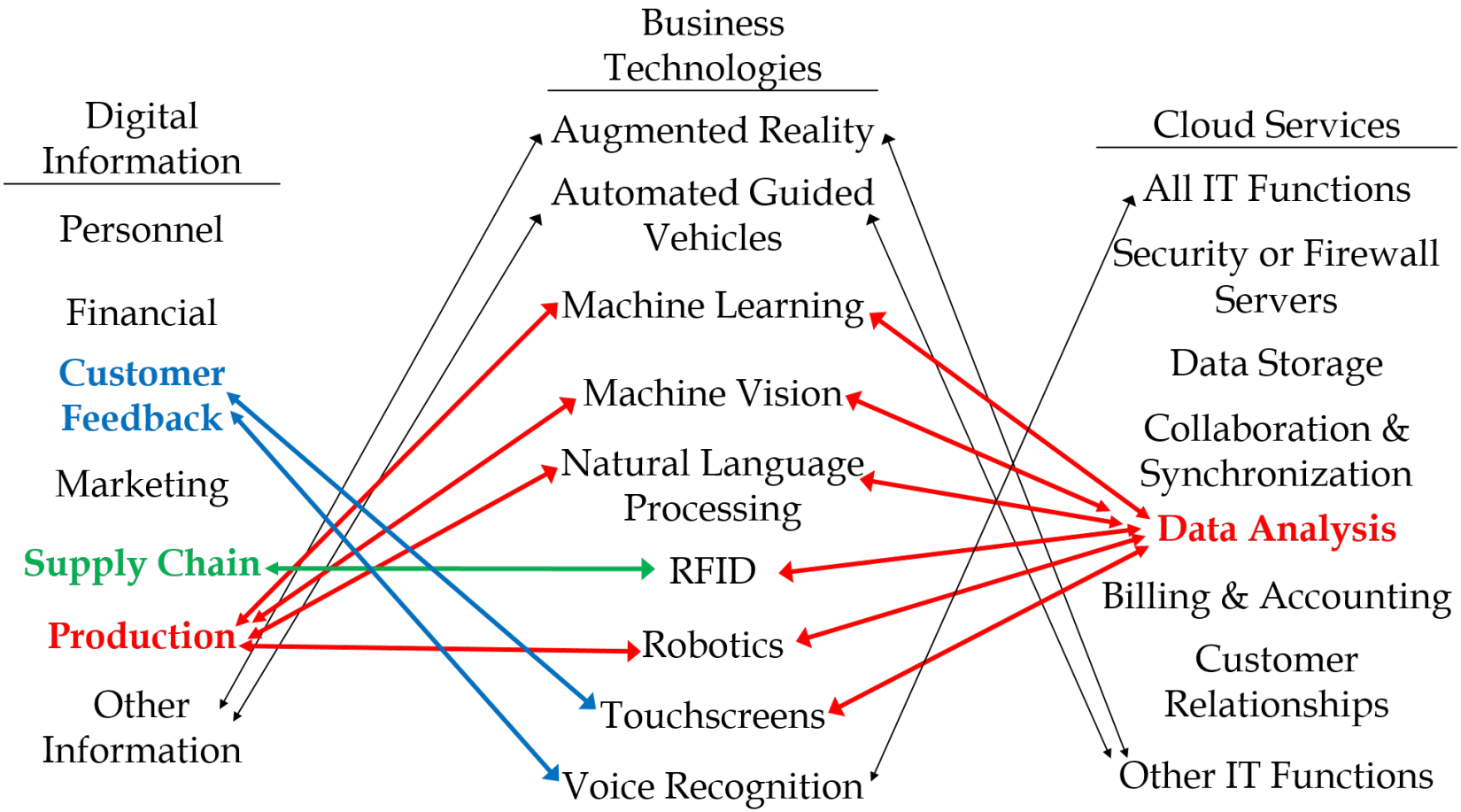
Digitization, Cloud Service and Business Technologies

- Connection between advanced technologies and (1) digitized **production** data and (2) cloud services for **data analysis**

▸ Resume ▸ Appendix



▸ Within Digital ▸ Within Bus Tech ▸ Within Cloud

United States Census Bureau

Most Correlated Pairs Within Digital Information (Q1)

Info Type 1	Info Type 2	Correlation Coeff.
Financial	Personnel	0.73
Marketing	Feedback	0.67
Supply Chain	Production	0.59
Supply Chain	Marketing	0.51
Financial	Marketing	0.50

▸ Resume ▸ Appendix

Most Correlated Pairs of IT Functions in the Cloud (Q2)

IT Function 1	IT Function 2	Correlation Coeff.
Servers	Security	0.73
Security	All IT	0.72
Servers	Data Storage	0.66
Servers	All IT	0.66
Data Storage	All IT	0.66

▸ Resume ▸ Appendix

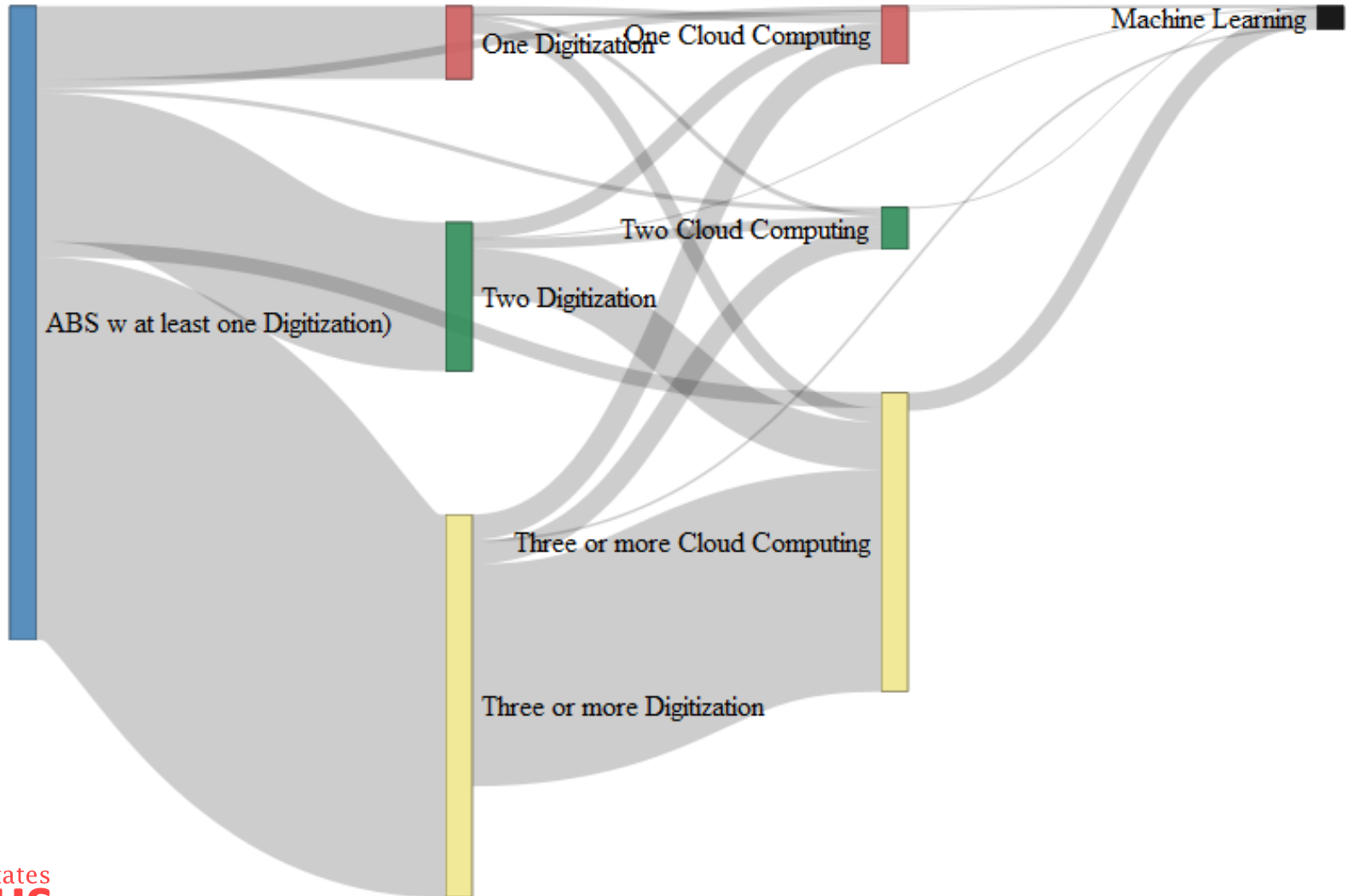
Most Correlated Pairs of Business Technologies (Q3)

Technology 1	Technology 2	Correlation Coeff.
Machine Learning	Machine Vision	0.52
Automated Vehicles	Augmented Reality	0.50
RFID	Automated Vehicles	0.40
Machine Vision	Natural Language	0.39
Natural Language	Automated Vehicles	0.38

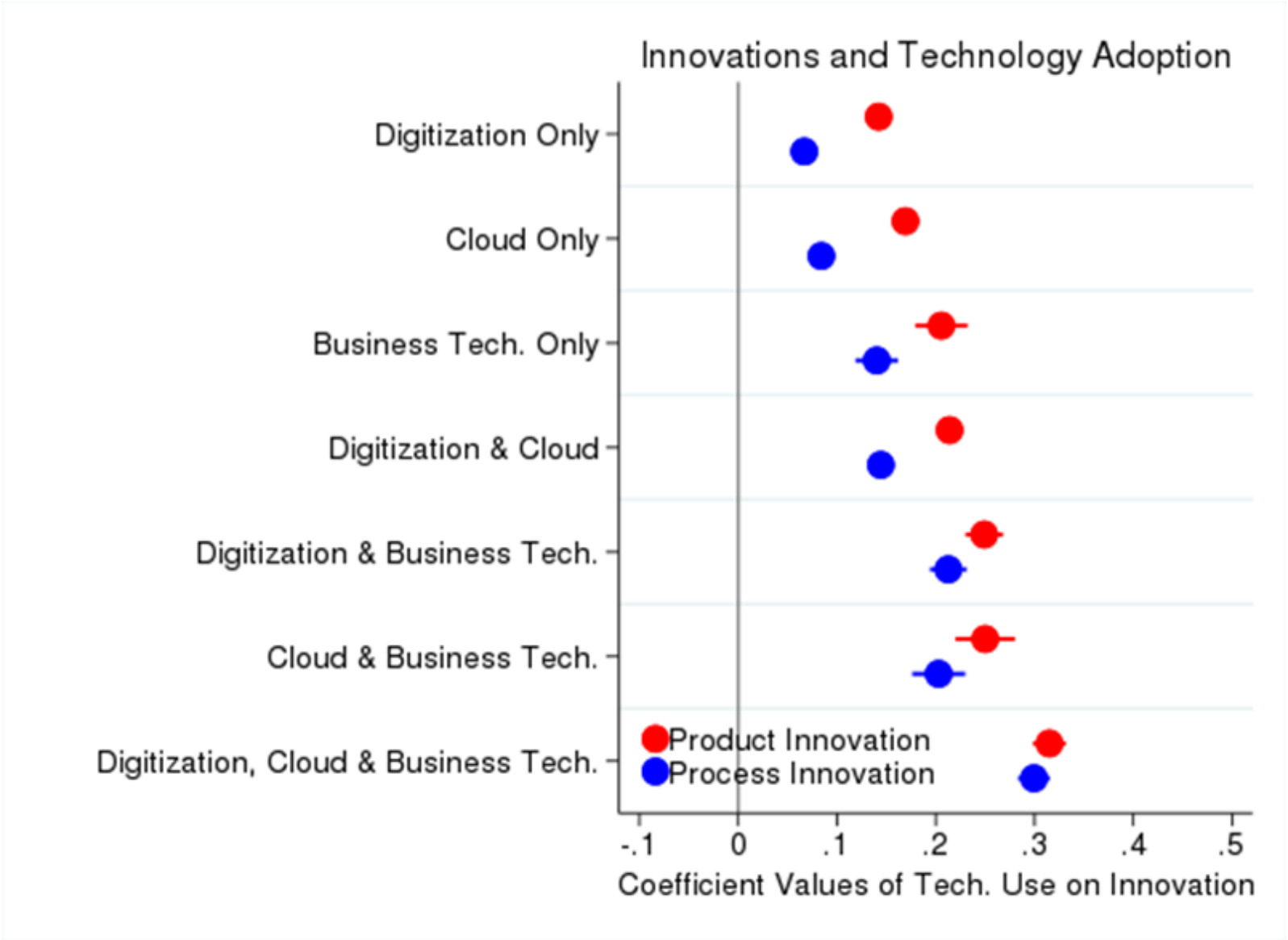
▸ Resume ▸ Appendix

Specific Technological Hierarchy: Machine Learning

- Technological infrastructure required for certain technologies can be significant



Innovation and Technology



Innovation and Technology

- Different types of technology adoption are more strongly associated with innovation outcomes